

The first confirmed Mira star in M 33

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ABSTRACT

We present photometry and moderate-resolution spectroscopy of the luminous red variable [HBS2006] 40671 originally detected as a possible nova in the galaxy M 33. We found that the star is a pulsating Mira-type variable with a long period of 665 days and an amplitude exceeding 7 mag in R band. [HBS2006] 40671 is the first confirmed Mira-type star in M 33. It is one of the most luminous Mira-type variables. In the K band its mean absolute magnitude is $M_K = -9.5$, its bolometric magnitude measured in the maximum light is also extreme, $M_{bol} = -7.4$. The spectral type of the star in the maximum is M2e – M3e. The heliocentric radial velocity of the star is -475 km/s. There is a big negative excess (-210 km/s) in radial velocity of [HBS2006] 40671 relative to the average radial velocity of stars in its neighborhood pointing at an exceptional peculiar motion of the star. All the extreme properties of the new Mira star make it important for further studies.

Key words: galaxies – optical: variable stars.

1 INTRODUCTION

The General Catalogue of Variable Stars (GCVS) (Kholopov et al. 1985) gives a determination of Mira (Omicron) Ceti-type variables: “These are long-period variable giants with characteristic late-type emission spectra (Me, Ce, Se) and variation amplitudes from 2.5 to 11 magnitudes in V . Their periodicity is well pronounced, and the periods lie in the range between 80 and 1000 days. Infrared amplitudes are usually less than those in the visible and may be < 2.5 mag. For example, in the K band they usually do not exceed 0.9 mag.” Due to the large amplitude of variability exceeding 2.5 mag in the V band, Mira variables in nearby galaxies may be confused with optical novae. The confusion can be solved, if subsequent spectral or photometric investigations reveal a Mira-type star with a cool M-type spectrum and a long periodic variability. Recently, peculiar red novae were introduced as a new class of astrophysical objects (e.g., Goranskij & Barsukova 2007). It is represented by stars such as V838 Mon, V4332 Sgr and V1006/7 in M 31. Nova Sgr 1943 (V1148 Sgr) may possibly also belong to this class. Their remnants may be cool luminous L- or M-type supergiants, which in the course of discovery may be confused with both Mira-type stars and classical novae. Nova

Sgr 1943 reached a maximum photometric brightness of 8.0 mag, it was described by Mayall (1949) as a late K-type star with TiO bands in the spectrum. It was found that the star is not of Mira-type, and later the star was lost.

In a search for novae in nearby galaxies one may run into similar problems. A cool supergiant may be misidentified as a nova when an unfiltered CCD image is compared with B or V images. The M 31 Nova candidate 2008-09b (Barsukova et al. 2008) turned out to be a star with M9-type spectrum. It may be a red nova or even a red supergiant showing no variability at all. There are two additional nova candidates in M 31 that turned out to be luminous Mira-type stars: M31N 1995-11e (Shafter et al. 2008a), M31N 2007-11g (Shafter et al. 2008b). The Mira-type star in IC 1613 described by Kurtev et al. (2001) has been discovered as a nova as well (King et al. 1999). In this paper we study a Mira-type star in the galaxy M 33, which has been discovered as a nova candidate.

An outburst of a source with coordinates $RA = 01^h34^m27^s.13$, $Dec = 30^\circ58'42''.7$ (J2000) in M 33 was detected by Nishiyama & Kabashima (2009). They reported it as a possible nova (with 18.6 mag) detected in five frames taken around 2009 August 17.807 UT exposed by 60 sec using the 0.40-m f/9.8 reflector and unfiltered CCD of the Miyaki Argenteus Observatory, Japan, reaching a limiting magnitude of 20.2. Nothing was visible at this location on

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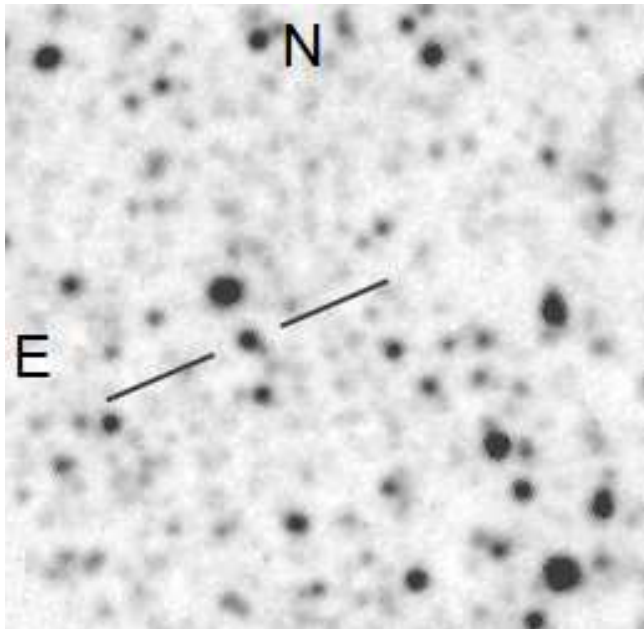


Figure 1. Finding chart of [HBS2006] 40671 made from the *R* band Subaru telescope frame taken on 2002 November 4. The new Mira-type star is marked by two lines. Size of the image is $25'' \times 25''$.

their previous frames taken on 2008 December 25.559 UT and 2009 August 07.737 UT with limiting magnitudes of 20.0 and 19.4, respectively. The source was confirmed by these authors on 2009 August 18.696. But later they withdraw the interpretation as possible nova as it did not change brightness.

The source was identified by us with a star number 40671 in the photometric survey of variable stars in M33 carried out by Hartman et al. (2006). We will name it hereafter [HBS2006] 40671. The survey observations were carried out between 2003 August and 2005 January. The authors classify the star as a Long Period Variable (LPV). During their observations (filled circles in Fig. 3), the star was red with $R - I \approx 2.7$ and ≈ 4.1 mag at maximum and minimum brightness, respectively. The star became extremely red during the registered minimum ($R \gtrsim 25$ mag).

2 OBSERVATIONS

We have carried out spectral observations with the Russian 6-m BTA telescope using the SCORPIO spectrograph (Afanasiev & Moiseev 2005). The spectrum has been taken on 2009 October 9.874 UT in a range 4300 - 7880 Å with spectral resolution of 13 Å. The spectroscopy was followed by *BVR_c* images on the same date. We found the star at a level of 18.8 mag in the *R_c* band. One more photometric *BVR_c* observation has been taken with the 1-m Zeiss telescope of the Special Astrophysical Observatory (RAS) on 2009 October 20.9 UT.

We have searched for additional images of this star in Internet archives of different observatories. Dozens of images were found, most of them come from medium-size telescopes equipped with wide field mosaic CCD cameras. The star position is well placed on the frames of the Calar Alto Obser-

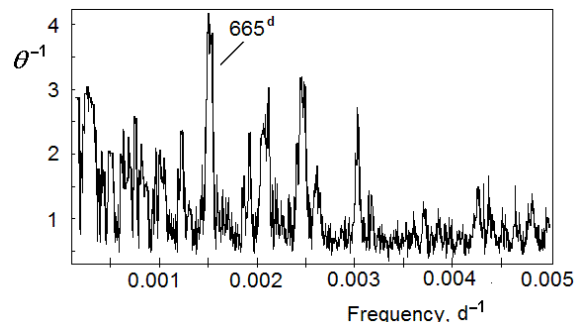


Figure 2. Periodogram of [HBS2006] 40671 calculated in the period range between 200 and 7000 days using the Lafler & Kinman (1965) phase dispersion minimization method. θ is a normalized dispersion parameter.

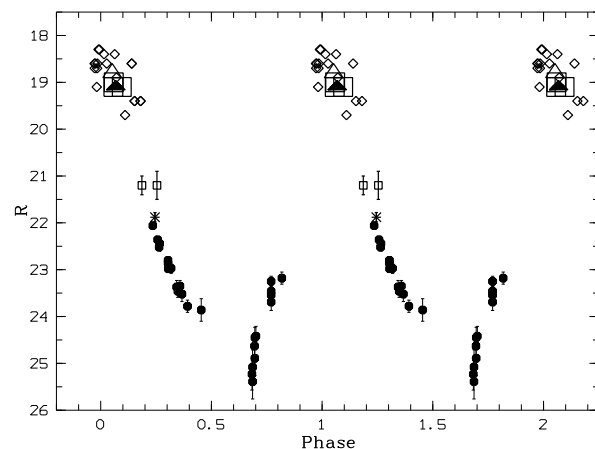


Figure 3. Light curve of [HBS2006] 40671 folded modulo the 665-day period in *R* band. Filled circles are the observations by Hartman et al. (2006). Big open squares indicate observations from Calar Alto, the asterisk from the Subaru telescope, open triangle from SAO BTA, filled triangle from SAO 1-m telescope, small open squares are Sloan *r'* magnitudes corrected by 0.6 mag. Open rhombs are unfiltered observations taken by (Nishiyama & Kabashima 2009) (error bars ~ 0.2 mag are not shown for clarity). At $R \gtrsim 25$ mag the accuracy of the estimates is not better than 0.4 mag.

vatory taken in 1989 and 1998 with the 80/120-cm Schmidt telescope, on the frames taken in 2001 and 2002 in *BVRI* bands with the 8.2-m SUBARU telescope of the National Astronomical Observatory of Japan. One *V* band observation from the 4.2-m William Herschel Telescope, and three SDSS *r'* band observations from the 2.54-m Isaac Newton Telescope were used as well, both telescopes belong to the Isaac Newton Group of Telescopes at the Roque de Los Muchachos Observatory at La Palma, Spain. We also apply one *I* band measurement obtained from the 4.0-m Mayall telescope image taken in 2001 and published by Massey et al. (2006).

Archival images from the 8.2-m SUBARU telescope, the 4.2-m William Herschel Telescope, and the 2.54-m Isaac Newton Telescope were downloaded as raw FITS files and then processed in the same way as our own 6-m BTA and 1-m Zeiss telescope images. Standard reduction procedures for raw CCD images were applied (bias and dark-frame sub-

Table 1. Photometric Observations of [HBS2006] 40671.

Date UT	JD 24...	Magnitude	Band ^a	Telescope
1989-10-03.11	47802.61	19.1±0.1	<i>R</i>	80/120 cm Calar Alto
1989-10-04.99	47804.49	19.0±0.1	<i>R</i>	80/120 cm Calar Alto
1998-10-29.03	47828.53	19.1	unfiltered	80/120 cm Calar Alto
2001-09-18.27	52170.77	20.66±0.09	<i>I</i>	4.0 m Mayall
2001-11-20.22	52233.72	19.2±0.1	<i>I</i>	8.2 m SUBARU
2001-11-20.39	52233.89	22.6±0.2	<i>V</i>	8.2 m SUBARU
2001-11-20.46	52233.96	>23.6	<i>B</i>	8.2 m SUBARU
2002-09-26.06	52543.56	21.8±0.2	<i>r'</i>	2.54 m Sloan INT
2002-11-04.23	52582.73	21.88±0.1	<i>R</i>	8.2 m SUBARU
2002-11-10.09	52588.59	21.8±0.3	<i>r'</i>	2.54 m Sloan INT
2004-09-10.08	53258.58	>23.1	<i>V</i>	4.2 m WHT
2008-10-09.12	54748.62	>24.4	<i>r'</i>	2.54 m Sloan INT
2009-08-17.81	55061.31	18.6	unfiltered	0.40 m f/9.8
2009-08-18.70	55062.20	18.7	unfiltered	0.40 m f/9.8
2009-08-19.75	55063.25	18.6	unfiltered	0.40 m f/9.8
2009-08-24.69	55068.19	19.1	unfiltered	0.40 m f/9.8
2009-08-25.71	55069.21	18.7	unfiltered	0.40 m f/9.8
2009-08-26.79	55070.29	18.6	unfiltered	0.40 m f/9.8
2009-08-29.77	55073.27	18.3	unfiltered	0.40 m f/9.8
2009-09-01.80	55076.30	18.3	unfiltered	0.40 m f/9.8
2009-09-15.69	55090.19	18.4	unfiltered	0.40 m f/9.8
2009-09-23.76	55098.26	18.6	unfiltered	0.40 m f/9.8
2009-10-09.8	55114.35	21.8±0.1	<i>B</i>	6.0 m BTA SAO RAS
2009-10-09.8	55114.36	20.02±0.05	<i>V</i>	6.0 m BTA SAO RAS
2009-10-09.8	55114.36	18.80±0.02	<i>R</i>	6.0 m BTA SAO RAS
2009-10-17.64	55122.14	18.4	unfiltered	0.40 m f/9.8
2009-10-20.91	55125.41	21.8±0.15	<i>B</i>	1.0 m SAO RAS
2009-10-20.91	55125.41	20.32±0.07	<i>V</i>	1.0 m SAO RAS
2009-10-20.92	55125.42	19.06±0.04	<i>R</i>	1.0 m SAO RAS
2009-10-22.74	55127.24	18.9	unfiltered	0.40 m f/9.8
2009-11-23.53	55153.03	19.7	unfiltered	0.40 m f/9.8
2009-12-07.53	55173.03	18.6	unfiltered	0.40 m f/9.8
2009-12-16.56	55182.06	19.4	unfiltered	0.40 m f/9.8
2010-01-03.52	55200.02	19.4	unfiltered	0.40 m f/9.8

^a For the plot of the light curve (Fig. 3), we subtracted 0.6 mag from Sloan *r'* magnitudes to transform them into *R* magnitudes (using color transformations from Jordi et al. (2006) and assuming an average color index $V - R = 1.2$ mag for the Mira-type star).

tract and flat-field correction) using the SIMS¹ program. Reduced images of the same series were co-added to improve the S/N ratio and then used for photometry. We used GAIA² to perform “Optimal photometry” (based on fitting of PSF profiles). *B*, *V*, *R*, and *I* magnitudes for comparison stars were taken from the Local Group Galaxy Survey (LGGS) catalog of stars in M33 (Massey et al. 2006).

In the case of SDSS *r'* band images, we computed *r'* magnitudes for comparison stars from *BVRI* magnitudes taken from Massey et al. (2006) using empirical color transformations between the SDSS *u'g'r'i'z'* system and Johnson-Cousins *UBVRI* system published by Jordi et al. (2006).

Nishiyama & Kabashima (2009) continued their unfiltered observations at the Miyaki Argenteus Observatory, Japan, from 2009 August 18 to 2010 January 3 and kindly provided us with 16 new images taken in this period. All the

photometric measurements of [HBS2006] 40671 (collected in addition to those of Hartman et al. 2006) are presented in Table 1.

We created a finding chart for the star from high-quality *R* band image taken with the Subaru telescope on 2002 November 4 (Fig. 1). A relatively bright visual companion is located 2.1 arcsec north-east of the variable. Massey et al. (2006) cataloged the position of this star as RA = 01^h34^m27^s.19, Dec = 30°58'44"4 (J2000) and give *B*, *V*, *R*, and *I* band magnitudes of 21.40, 21.11, 20.94, and 20.71, respectively. The observations of the LGGS (Massey et al. 2006) were obtained from October 2000 to September 2001. The variable star is not included in the catalog, as it is only detected on the *I* band image taken during the survey on 2001 September 18 (criterion for inclusion in catalog is detection in the three bands *B*, *V*, *R*).

¹ <http://ccd.mii.cz/>

² <http://www.starlink.rl.ac.uk/gaia>

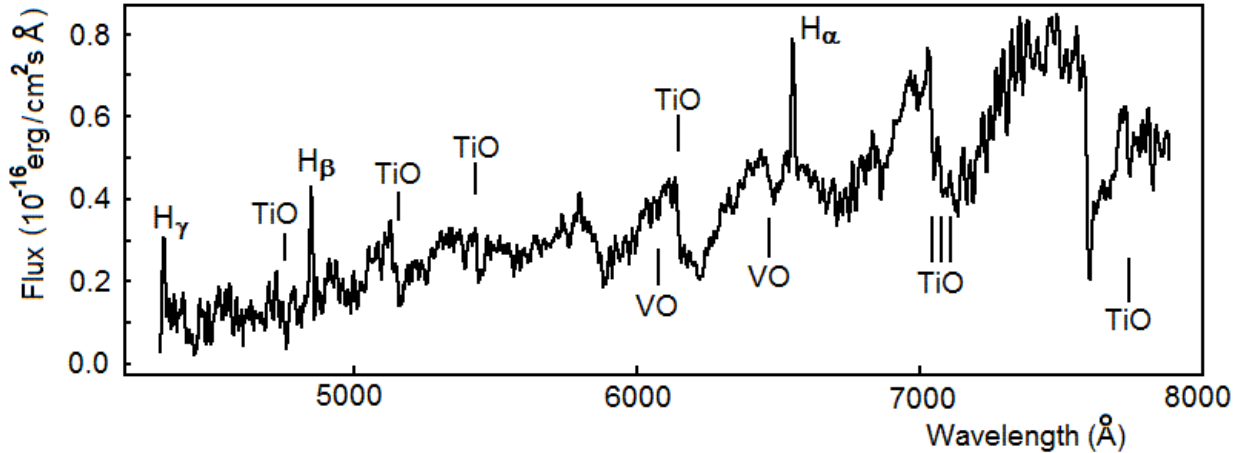


Figure 4. The spectrum of [HBS2006] 40671 taken with BTA on 2009 October 9 near the maximum light.

3 THE PERIOD SEARCH AND THE LIGHT CURVE

Most of the data in Table 1 relate to the light curve maximum. Both ascending and descending branches of the light curve are not fully covered. The observations during these phases come mostly from the survey by Hartman et al. (2006). The survey presents observations when the star had a brightness between 22 and 25 mag in the *R* band. The accuracy of these observations (Hartman et al. 2006) varies from 0.04 mag at *R* = 22 mag to 0.37 mag at *R* = 25 mag.

To search for periodicities we used a method proposed by Lafler & Kinman (1965) which is based on the phase dispersion minimization. In this search we used only the observations in *R* band because they represent the best sampling among the total data set.

The periodogram was calculated in the period range between 200 and 7000 days (Fig. 2). The output parameter there is the inverse dispersion value $1/\theta$ described by Lafler & Kinman (1965), maxima in the periodogram correspond to dispersion minima. There are essentially no peaks with period values less than 200 days. This range of periods is not shown in the figure. A period of 665 days shows the highest amplitude. There are two lower amplitude peaks at 3500 and 406 days (Fig. 2). However, these periods give much worse light curves. Longer periods contradict with the fast changes of brightness on ascending and descending branches of the light curve (Hartman et al. 2006). The phased light curve in the *R* band is presented in Fig. 3. It was calculated with the following light elements

$$Max = 2455080 + 665 * E. \quad (1)$$

Figure 3 shows that we do not resolve and possibly not even cover the minimum of the light curve. The star in minimum brightness is not brighter than *R* = 25.4 mag. The total amplitude of the variability is bigger than 7 mag in the *R* band. Also the ascending branch is not well covered. Therefore, the epoch of the maximum can only be constrained to ± 5 days. However, it is obvious that the light curve of this Mira variable is asymmetric, the ascending branch is steeper than the descending one.

We tried to refine the maximum in the light curve us-

ing archival observations of the infrared satellite Spitzer (McQuinn et al. 2007). In five observations on 2004 January 09, July 22, August 16, and 2005 January 21 and August 25, the star varied in the range of 14.24 – 14.97 mag, 14.16 – 14.64 mag, and 13.66 – 14.04 mag in the 3.6, 4.5, and 8 μ m bands, respectively. A maximum is found during July/August 2004 corresponding to phases in the interval 0.18–0.22 according to Equation 1. Therefore the infrared maximum seems not to be in phase with the optical maximum exactly, but it is very close to it (see Fig. 3).

4 SPECTRUM

The calibrated spectrum of [HBS2006] 40671 in the 4300 – 7880 Å spectral region is shown in Fig. 4. Molecular TiO bands dominate in the spectrum. We classify the star as an oxygen-rich (M-type or O Mira) star (Smak 1964; Jaschek & Jaschek 1987). Strong narrow emission lines of hydrogen are present as well; this is typical for Mira stars during maximum light. Using the spectrum we estimate a contribution of the TiO bands into the star brightness in *B* and *V* bands. They are $\delta(B) = -0.28$ mag and $\delta(V) = -0.16$ mag. These values agree with the spectral type M1 – M2 (Smak 1964).

We have also determined the spectral type of the star using $[TiO]_1$ and $[TiO]_2$ indices introduced by O’Connell (1973) and measured in our calibrated spectrum. The spectral indices were derived from fluxes measured in 30 Å bandpasses centered at three wavelengths each for $[TiO]_1$ (6125, 6180 and 6370 Å) and for $[TiO]_2$ (7025, 7100 and 7400 Å) as $[TiO]_1 = +0.52$ and $[TiO]_2 = +0.55$, respectively. These index values correspond to spectral class M3. Such a spectrum is natural for Mira variables in maximum light, while in the minimum they have usually later spectra.

The $H\alpha$ emission line of [HBS2006] 40671 is very narrow and not resolved in our spectrum. Its equivalent width is $EW = 9$ Å. For $H\alpha$ we measure a heliocentric radial velocity of -440 ± 15 km/s. That this high radial velocity is not caused by calibration problems was verified by measuring the radial velocity of the [OI] $\lambda 6300$ sky line which was determined as 0 km/s as expected. Also, at a distance

of $\sim 1.6'$ from [HBS2006] 40671, by chance the high ionization HII region Z378 (Courtes et al. 1987) was captured in the slit. The heliocentric radial velocity of its H α line is -280 ± 10 km/s. This velocity is in good agreement with that of the HI radio emission at the position (-265 ± 5 km/s, Reakes & Newton 1978). The difference of $1.6'$ between the HII region and the star's location in the galaxy body may produce a radial velocity shift of $5 - 10$ km/s. Therefore we find a strong negative excess in the H α radial velocity of [HBS2006] 40671 of -175 km/s over the galaxy radial velocity.

To check whether this negative excess of the H α radial velocity also is reflected in other features of the spectrum of [HBS2006] 40671, we cross-correlated it with spectra of known standard stars. We used two red variables, V934 Her (HD 154791, 4U 1700+24, M2 III) and KK Per (HD 13136, M2 Iab-Ib). The cross-correlation region was $5850 - 6700$ Å excluding H α emission and interstellar NaI lines. The spectrum of V934 Her was taken with the SAO 1-m Zeiss telescope on 2006 April 6.95 UT. According to Galloway et al. (2002) it is an X-ray binary with a period of $P = 404 \pm 3$ days. The radial velocity amplitude of the primary is only $K = 0.75 \pm 0.12$ km/s. The systemic velocity of V934 Her is -48.7 ± 0.1 km/s. The cross-correlation resulted in a radial velocity of -474 km/s for the Mira star. We obtained almost the same value (-477 km/s) using the second standard star KK Per (its radial velocity is -39.4 ± 0.4 km/s, Marrese et al. 2003).

We conclude that the star has a big negative peculiar radial velocity compared to the body of the galaxy (HI data) of -210 ± 10 km/s. Its H α emission is redshifted relative to the star by $+35 \pm 10$ km/s. Such a shift might be explained by stellar pulsations. However, it could also be caused by the superposition of the emission line on an absorption line that is not resolved in our spectrum. The huge peculiar velocity can not be explained by the star binarity. To get an orbital velocity of ~ 200 km/s in a few solar mass binary the orbital period must be less than 10 days, and the orbital separation less than 0.2 a.u. This is impossible due to the huge sizes of Miras.

We tried to investigate if [HBS2006] 40671 is positioned in front of or behind the disk of M33 which would indicate motion away from or to the disk, respectively. However, the signal to noise of the spectrum in the range of expected diffuse interstellar bands (e.g. Cordiner et al. 2010) was not sufficient.

5 DISCUSSION AND CONCLUSION

According to our data from the 6-m and 1-m telescopes, the observed photometric colours of [HBS2006] 40671 during maximum are $B - V = 1.6$ and $V - R = 1.2$ mag. Taking into account the distance modulus of M33 ($m - M$) $_0 = 24.92 \pm 0.12$ mag (the distance 964 ± 54 kpc, Bonanos et al. 2006) and the Galactic extinction value $A_V = 0.15$ mag ($A_K = 0.02$ mag) in that direction (Schlegel et al. 1998) we find an absolute magnitude of the star near maximum brightness ($V = 20.02 \pm 0.05$ mag at the pulsation phase 0.05) of $M_V = -5.05 \pm 0.15$. This is consistent with luminosity classes Ib-Iab. For an M3-type star the bolometric correction amounts to -2.34 mag (Smak 1966). This leads

to a bolometric magnitude in the brightness maximum of $M_{bol} \approx -7.4$. Unfortunately, we have not enough data to estimate V band pulsation magnitude or mean magnitude.

2MASS data (Skrutskie et al. 2006) show [HBS2006] 40671 on 1997 December 5, in the pulsation phase of 0.54, at a brightness of 17.30 ± 0.23 , 15.89 ± 0.16 and 15.45 ± 0.15 mag in J , H and K , respectively. There are more observations of the star in the JHK bands taken from 2005 September 29 to December 16 (pulsation phases 0.84–0.96) with the 3.8-m UKIRT telescope equipped with WFCAM (Cioni et al. 2008). The brightness of the star during this period was 16.86, 16.24 and 15.66 mag in the JHK bands, respectively. These data confirm the typical Mira behaviour, i.e. the decrease of pulsation amplitude with increasing wavelength. However we have not enough data to study the infrared light curve in detail. Kanbur et al. (1997) found that the K band amplitudes of O Mira variables is smaller for shorter periods. From the relations in that paper, the O Mira variables with periods longer than 420 days should show total K amplitudes smaller than 0.4 mag. We use the 2MASS data for a luminosity estimate. We find an absolute magnitude of the [HBS2006] 40671 as $M_K \sim -9.5$ with a possible error of ± 0.15 . Applying a bolometric correction of $+3.3$ mag determined by Bessell & Wood (1984) to this K band magnitude we find $M_{bol} = -6.2$.

Feast et al. (1989) present period - luminosity (PL) relations for LMC Mira variables, where they found that the O Mira variables with periods longer than ~ 420 days are over-luminous (see also Hughes & Wood 1990). Fitting the over-luminous branch of the long-period Mira variables (without the star C2 whose status is less certain, Feast et al. 1989) we find for our star with the 665-day period that the expected mean luminosity is $M_K \sim -9.47$ mag. This agrees well with our estimate from the 2MASS data. Using PL relations for bolometric luminosities for the over-luminous long-period Mira variables both from Feast et al. (1989) and Hughes & Wood (1990) we find very similar results, the mean expected luminosity for the 665-day star is $M_{bol} \approx -6.5$ mag. This value is close to $M_{bol} = -6.2$, found above from the 2MASS data taken in the minimum. On the basis of our spectral classification, we determined the bolometric luminosity of ≈ -7.4 mag is in the brightness maximum. The bolometric luminosities of O-type Mira variables are notably changing during the pulsation cycle. Using the relations found by Kanbur et al. (1997) one may expect that in O Mira variables with periods longer than 420 days the difference between maximal and mean bolometric luminosity is larger than 0.5 mag. We conclude that luminosities of [HBS2006] 40671 found by us are in line with the statistical relations, but the star's parameters put it in the extreme tail of these relations.

In the presence of the huge amplitude of [HBS2006] 40671 in the R band, not less than 7 mag, one may expect an even larger amplitude in the V band (e.g. Barthes, Chenevez, & Mattei 1996). In the long-period Mira variables the amplitude dispersion is very high (Mattei et al. 1997; Hughes & Wood 1990). A visual amplitude in a Mira star with a period $P \sim 665$ days may be as large as 8.3 mag (Mattei et al. 1997). Using relations presented by Hughes & Wood (1990) we estimate a mass of this star as $M \sim 4$ solar masses. Based on its luminosity and the pulsation period, [HBS2006] 40671 is similar to the

Mira-type variable discovered by Kurtev et al. (2001) in the IC 1613 galaxy ($M_K = -9.62$ mag and $P = 640.7$ day). However the amplitude of the IC 1613 Mira is only $2.5 - 3$ mag in R band. In the PL plane for M_K luminosities for LMC the star [HBS2006] 40671 is located in the same place as the IC 1613 Mira (Kurtev et al. 2001). Both stars are located in the zone of the first-overtone pulsating Mira variables.

Wood et al. (1983) found that long-period variables are grouped into two classes: core-helium-burning supergiants which are brightest, and AGB stars which are at least 1 mag fainter at a given period. The supergiant LPVs form a distinct PL relation and they have lower amplitudes. The PL relation for six core-helium-burning supergiants in M 33 was presented by Kinman et al. (1987) in their Fig. 8. The K magnitude for supergiants with the 665 day period is expected to be 13.9. The 2MASS K magnitude of [HBS2006] 40671 is 1.5 mag fainter, what suggests that this object is an AGB star. AGB stars in M 33 and M 31 are discussed in papers by Javadi et al. (2010) and Rich et al. (1993).

Whitelock (2010) discussed a type of long-period variables which are undergoing a hot bottom burning (HBB) in the base of their convective envelopes. They lie above the PL relation of AGB Mira-type variables. In LMC they are large amplitude variable stars additionally showing a lithium and s-process enrichment. As an example, she refers to 641-day Mira in IC 1613 studied by Kurtev et al. (2001) that locates above the PL relation. [HBS2006] 40671 also locates 0.35 mag above the PL relation for AGB stars with periods over 400 days derived by Hughes & Wood (1990) along with three HBB stars studied by Whitelock et al. (2003) in LMC. We did not find lithium or other s-process elements in our low-resolution spectrum, but the luminosity excess is evident as that in the IC 1613 Mira variable.

We conclude that the star [HBS2006] 40671 in M 33 is O Mira-type variable with extreme properties. Its pulsation amplitude is not less than 7 magnitudes in R band, the period of ~ 665 days is one of the longest known for Mira-type variables. The mean absolute magnitude of the star in K band is $M_K \sim -9.5$. In maximum light its bolometric magnitude is estimated as $M_{bol} \approx -7.4$. It shows a spectrum of type M2e–M3e.

There is a strong negative excess of -210 km/s in the star velocity relative to the radial velocity of the star's location projected to the galactic disk. This is a peculiar motion of the star. According to Feast (2007) the velocity dispersion of Galactic O-Miras is in the range 30 to 80 km/s. They belong to the galactic populations ranging from the thin disk to the extended disk. In spite of the enhanced velocity dispersion of the Galactic Mira-stars the peculiar velocity of ~ -200 km/s in the [HBS2006] 40671 is rather big.

The radial velocity of the narrow $H\alpha$ emission line is $+35 \pm 10$ km/s relative to that of the star itself. Such a shift in the $H\alpha$ emission is typical for Mira stars. It can be explained by stellar pulsations and shocks in an expanding atmosphere. All the properties make the new Mira star important for further studies. [HBS2006] 40671 is the first spectroscopically confirmed Mira star in M 33.

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